



ANSI/ASHRAE/IESNA Standard 90.1

U.S. Department of Energy
Building Energy Codes Program

Produced by the Pacific Northwest National Laboratory





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 - Text used verbatim from the Standard in these materials is marked in quotes
- 2001 NOTE: Red/underlined items in these materials illustrate 90.1-2001 requirements



DOE's Interest in 90.1

- Per the requirement in the Energy Policy Act of 1992
 - DOE has “determined” that Standard 90.1-1999 saves energy over Standard 90.1-1989
 - States now have two years to notify DOE that they have adopted a commercial energy code that meets or exceeds Standard 90.1-1999



DOE's Determination

- For more information on the determination
 - www.energycodes.gov
- DOE estimates that, overall, Standard 90.1-1999 saves about 5% over Standard 90.1-1989
 - Savings are primarily associated with lighting and some mechanical equipment



Why is Standard 90.1 important?

- It replaces ANSI/ASHRAE/IESNA Standard 90.1-1989 and the codified version of Standard 90.1-1989 (the gray book)
- It is the reference standard for Chapter 7 of the 2001 IECC
- It is also the commercial energy reference in NFPA's family of codes



How has it changed since 90.1-1989?

- Written in mandatory, enforceable language
- Contains true prescriptive path for envelope
- Mechanical and envelope sections heavily dependent on economic analysis
- Lighting section heavily dependent on lighting quality considerations
- Pays considerable more attention to existing buildings



How has it changed?

- Does not include lighting tradeoff software (LTGSTD)
- Does include a simplified mechanical systems approach for “simple” buildings
- Does include separate envelope requirements for non-residential, residential, and semi-heated spaces
- Is accompanied by ASHRAE Guideline 18 (ways to go beyond Standard 90.1) – *in process*
- Extends scope and coverage (alterations and additions)
- Includes international units
- Expands climate locations
- Is reorganized for ease of use



How is it the same?



- Contains separate envelope, HVAC, SWH, and lighting provisions
- Includes envelope tradeoff software (ENVSTD – new version)
- Contains an energy cost budget tradeoff method



How has stringency changed?

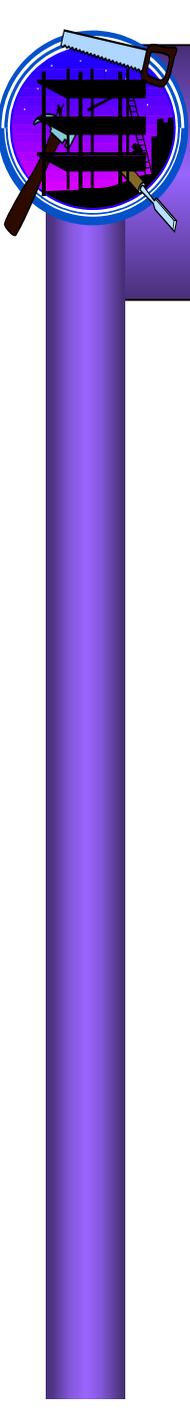
- Mechanical requirements generally more stringent (with exception of economizers)
- Envelope requirements a mixed bag – some more stringent, some less, depending on economics
- Lighting requirements generally more stringent with exception of some building types and space types



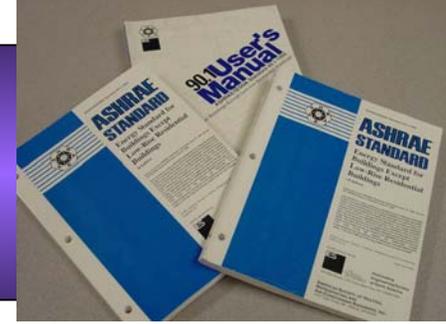


How can I find out more about the differences?

- Excruciatingly detailed comparisons of Standards 90.1-1989 and 90.1-1999 may be found at http://www.energycodes.gov/implement/determinations_com.stm
- PNNL is also working on comparisons of the 90.1-1999 Standard and Chapter 8 of the 2001 IECC



How can I get a copy?



- Standard 90.1, the Standard 90.1 Users Manual, and the ENVSTD software are available from ASHRAE



www.ashrae.org



404-636-8400



Comparison of organization of sections of Standard 90.1

90.1-1989

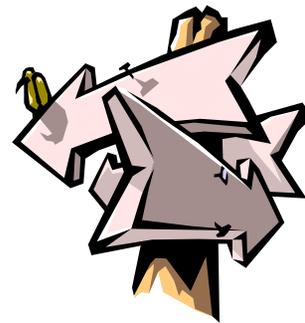
- 4 – Compliance
- 5 – Electric power
- 6 – Lighting
- 7 – Auxiliary systems and equipment
- 8 – Building Envelope
- 9 – HVAC Systems
- 10 – HVAC Equipment
- 11 – SWH
- 12 – Energy management
- 13 – ECB

90.1-1999

- 4 – Administration and enforcement
- 5 – Building envelope
- 6 – HVAC
- 7 – SWH
- 8 – Power
- 9 – Lighting
- 10 – Other equipment
- 11 – ECB

90.1-2001

Same as 90.1-1999 with the addition of Appendix F - Addenda





Standard 90.1

Section 1 - Purpose

Section 2 - Scope

Section 3 - Definitions, Abbreviations, and Acronyms

Section 4 - Administration and Enforcement

Section 5 - Building Envelope

Section 6 - Heating, Ventilating, and Air-Conditioning

Section 7 - Service Water Heating

Section 8 - Power



Standard 90.1

Section 9 - Lighting

Section 10 - Other Equipment

Section 11 - Energy Cost Budget Method

Section 12 - Normative References

Appendices A-D - Mostly envelope related

Appendix E - Informative References

Appendix F – Addenda Description
Information



Section 1 - Purpose

To provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings



Section 2 - Scope



- New buildings and their systems
- New *portions* of buildings and their systems (additions)
- New systems and equipment in *existing* buildings (alterations)



Section 2 – Scope *(cont'd)*

- Envelope
 - if heated by a heating system with an output capacity $\geq 3.4 \text{ btu/h-ft}^2$ or
 - if cooled by a cooling system with a sensible output $\geq 5 \text{ btu/h-ft}^2$
- Virtually all mechanical and lighting systems are covered



Scope exceptions

- Too little heating or cooling
- Single-family, multifamily of three stories or less, manufactured or modular homes
- Buildings that don't use electricity or fossil fuel
- Equipment and portions of building systems that use energy primarily for industrial, manufacturing, or commercial purposes



Section 3 - Definitions, Abbreviations, and Acronyms

- Over 10 pages of definitions
- 1 page of abbreviations and acronyms
- Defined terms are italicized in text of standard



Section 4 – Administration and Enforcement

- Specifies
 - what applies to new buildings, existing buildings, additions, and alterations
 - exemptions for envelope, HVAC, SWH, power, lighting, and other equipment alterations
- Discusses changes in space conditioning



Administration and Enforcement *(cont'd)*

- Addresses
 - compliance documentation
 - labeling of materials and equipment
 - fenestration, doors, insulation, mechanical equipment, and packaged terminal air conditioners
 - alternative materials and methods of construction
 - inspections



Section 5 – Building Envelope

- General (*Section 5.1*)
 - Scope
 - Compliance
 - Climate
 - Space-Conditioning Categories and Basis
- Mandatory Provisions (*Section 5.2*)
 - Insulation
 - Fenestration and Doors
 - Air Leakage
- Prescriptive Building Envelope Option (*Section 5.3*)
 - Opaque Areas
 - Fenestration
- Building Envelope Trade-Off Options (*Section 5.4*)



Scope *(Section 5.1.1)*

- Envelope components that enclose
 - conditioned space
 - semi-heated space
- Requirements apply to three types of spaces
 - Nonresidential
 - Residential
 - Semi-heated
- Exceptions





Semi-heated space

- Has a heating system with a capacity $> 3.4 \text{ Btu/h.ft}^2$ (10 W/m^2) of floor area but is not conditioned space

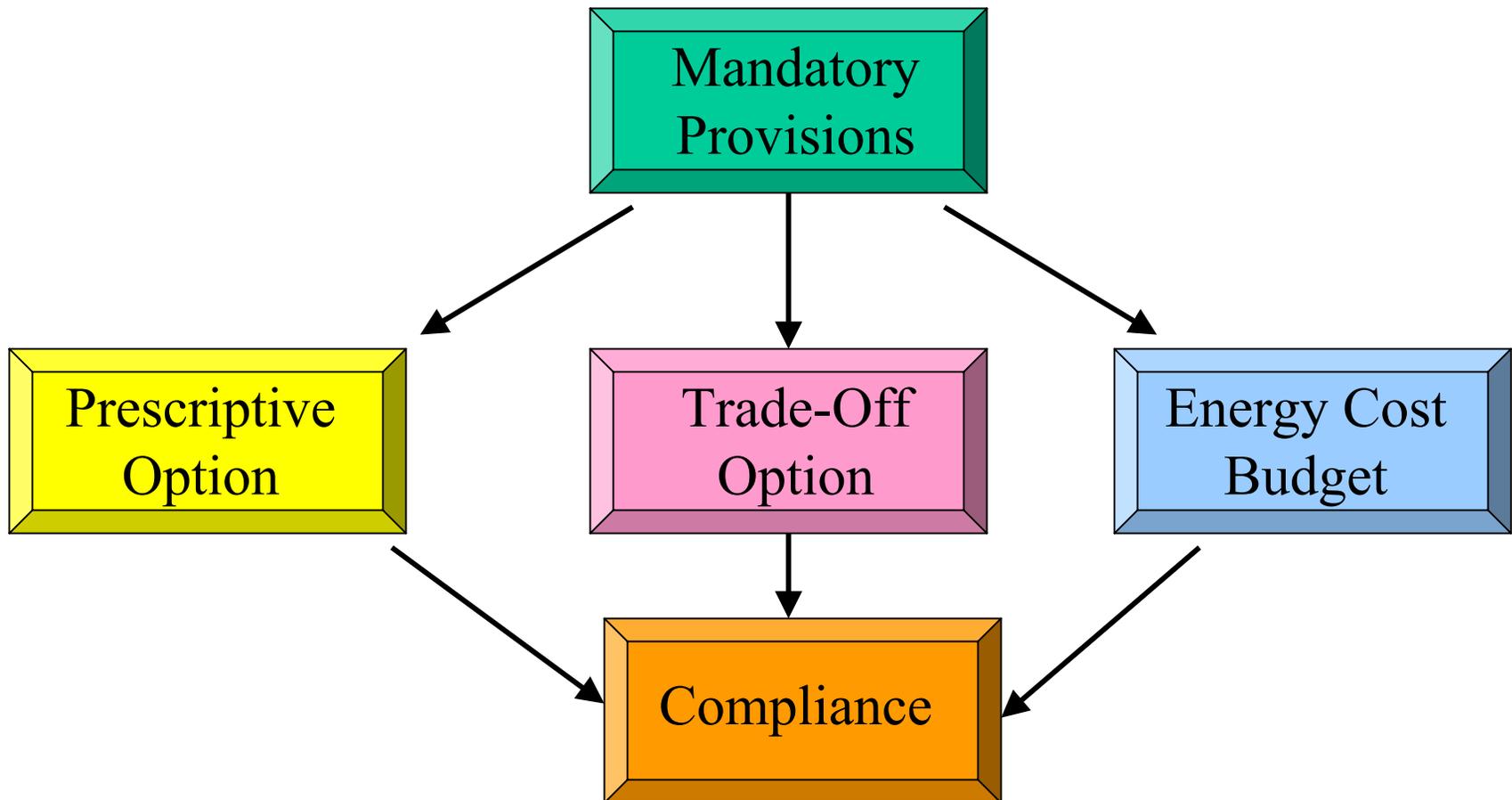


Exceptions

- All semi-heated and unconditioned spaces to be clearly indicated on floors plans
- In climates > 1800 HDD65, space may be designated either semi-heated or unconditioned only if approved by the building official



Envelope Compliance Methods *(Section 5.1.2)*

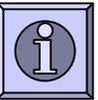




Climate *(Section 5.1.3)*



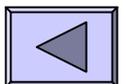
- Bins based on CDD50 and HDD65
 - Locations listed in Appendix D
 - If location not listed, select one with “closest” climatic conditions





CDD and HDD

- CDD50 = for any one day, when the mean temperature is $> 50F$, there are as many degree-days as degrees F temperature difference between mean temperature and $50F$. Annual cooling degree days (CDD) are the sum of the degree-days over a calendar year.
- HDD65 = for any one day, when the temperature is $< 65F$, there are as many degree-days as degrees F temperature difference between mean temperature and 65 . Annual heating degree-days (HDD) are the sum of the degree-days over a calendar year.





Space-Conditioning Categories and Basis Envelope Requirements Are Specified by Space-Conditioning Categories (Section 5.1.4)

- Each space to be included in a category
 - Nonresidential conditioned space
 - Residential conditioned space
 - Both nonresidential and residential semiheated space
- Spaces in climates > 1800 HDD65 assumed to be conditioned space unless
 - space will only be semiheated or unconditioned and
 - approved as such by the building official



Mandatory Provisions

Mandatory Provisions

(Section 5.2)

- Insulation (*Section 5.2.1*) (*Section 5.5.1*)
 - Installation (*Section 5.5.1.1*)
 - Substantial contact (*Section 5.5.1.2*)
 - Recessed equipment (*Section 5.5.1.3*)
 - Location of roof insulation (*Section 5.5.1.4*) and insulation protection (*Section 5.5.1.5*)

Section 5.2.1 now simply refers to Section 5.5

Required in all compliance paths



Insulation Installation

(Section 5.2.1.1) (Section 5.5.1.1)

- Per manufacturer's instructions
- Achieve rated R-value
- No open-blown or poured loose-fill insulation
 - when ceiling slope is $> 3/12$
- If eave vents installed
 - provide baffling of air vents "to deflect incoming air above the surface of the insulation"
- Metal buildings exception
 - If roof and wall insulation is "compressed between roof or wall skin and the structure"



Substantial Contact

(Section 5.2.1.2) (Section 5.5.1.2)

- Install insulation in a “permanent manner in substantial contact with inside surface”
- Flexible batt insulation in floor cavities
 - to be “supported in a permanent manner by supports no more than 24 in. o.c.”



Recessed Equipment

(*Section 5.2.1.3*) (*Section 5.5.1.3*)

- Do not recess equipment to affect insulation thickness
 - Lighting fixtures
 - HVAC equipment (includes wall heaters, ducts, and plenums)
 - Other
- Exceptions





Exceptions

- When
 - “Total combined area affected (include necessary clearances) is $< 1\%$ of opaque area of the assembly, **OR**
 - Entire roof, wall, or floor is covered with insulation to the full depth required, **OR**
 - Effects of reduced insulation are included in area-weighted calculations”





Mandatory Provisions

Roof Insulation (*Section 5.2.1.4*) (*Section 5.5.1.4*)

- Not “installed on a suspended ceiling with removable ceiling panels”



Insulation Protection

(Section 5.2.1.5) (Section 5.5.1.5)

- Cover exterior insulation with protective material
 - Sunlight
 - Moisture
 - Landscaping operations
 - Equipment maintenance
 - Wind
- Access to attics and mechanical rooms without damaging or compressing insulation
- “Insulation materials in ground contact to have a water absorption rate # 0.3%₃₅ (ASTM C272)”



Fenestration and Doors

(Section 5.2.2) (Section 5.5.2)

- U-factors
 - NFRC 100 or
 - Assemblies listed in Appendix A
- SHGC
 - NFRC 200 or
 - Assemblies listed in Appendix A
- Visible Light Transmittance
 - NFRC 200 when building envelope trade-off option is used





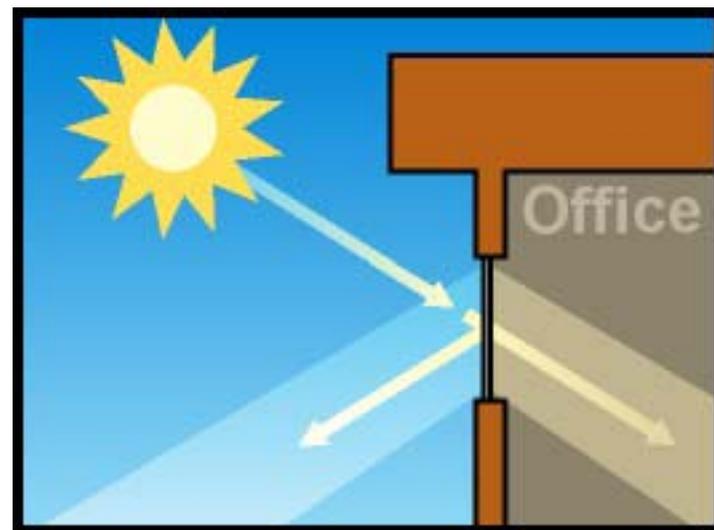
U-factor

- Skylights – determine for a slope of 20° above the horizontal
- Labeled and certified by manufacturer
- Exceptions
 - “Glazed wall systems in vertical fenestration and skylights” – may use U-factors in A.8.1
 - A.8.2 acceptable for other vertical fenestration
 - A.7 acceptable for opaque doors
 - NAGDM 105 acceptable for garage doors



Solar heat gain coefficient

- The glazing's effectiveness in rejecting solar heat gain
- Part of a system for rating window performance
 - used by NFRC
- Gradually replacing shading coefficient (SC) in product literature and design standards





SHGC *(cont'd)*

- Overall fenestration area (NFRC 300)
 - SC X 0.86
 - SHGC for center of glass
- SHGC from A.8.1 for glazed wall systems in vertical fenestration and skylights
- SHGC from A.8.2 for other vertical fenestration



Visible light transmittance

- A measure of the amount of visible light that passes through fenestration
- Affected by:
 - composition of the glass
 - coatings
 - internal shading devices



Air Leakage (Section 5.2.3)

(Section 5.5.3)



- Seal, caulk, gasket, or weather-strip
 - openings and joints in building envelope
 - fenestration and doors per NFRC 400
 - loading docks in climates > 3600 HDD
 - vestibules and doors separating conditioned space from exterior





Building Envelope Sealing

(Section 5.2.3.1) (Section 5.5.3.1)

- Joints around fenestration and door frames
- Junctions between walls
 - and foundations
 - at building corners
 - and structural floors or roofs
 - and roof or wall panels
- Openings for “utility services through roofs, walls, and floors
- Site-built fenestration and doors
- Building assemblies used as ducts or plenums
- Joints, seams, and penetrations of vapor retarders
- All other openings in the building envelope”



Fenestration and Doors

(Section 5.2.3.2) (Section 5.5.3.2)

- NFRC 400
- Labeled and certified by manufacturer
- Glazed swinging entrance doors and revolving doors – not to exceed 1.0 cfm/ft²
- All other products – not to exceed 0.4 cfm/ft²
- Exceptions
 - “Field-fabricated fenestration and doors”
 - Garage doors – NAGDM 105



Loading Dock Weatherseals

(Section 5.2.3.3) (Section 5.5.3.3)

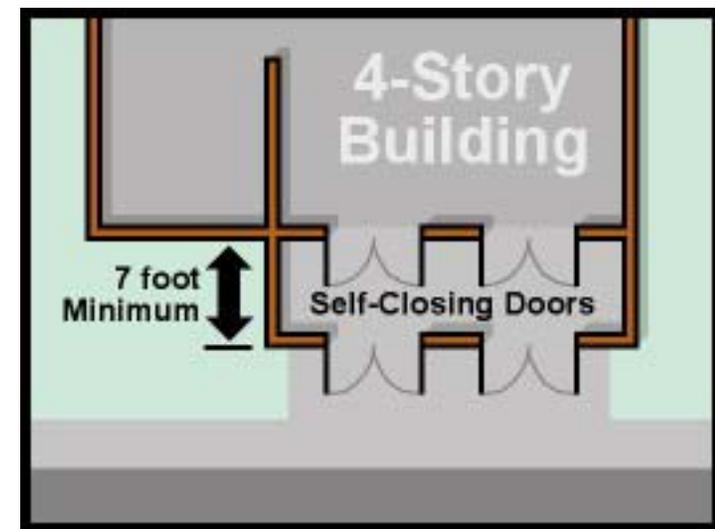
- > 3600 HDD65
 - “Cargo doors and loading dock doors equipped with weatherseals
 - To restrict infiltration when vehicles are parked in the doorway”





Vestibules (Section 5.2.3.4) (Section 5.5.3.4)

- All exterior doors in tall buildings in cold climates must have a vestibule with
 - self-closing doors
 - interior and exterior doors must not be open at the same time
 - distance between interior and exterior doors not < 7 ft when in closed position (remember ADA!)





Vestibule exceptions

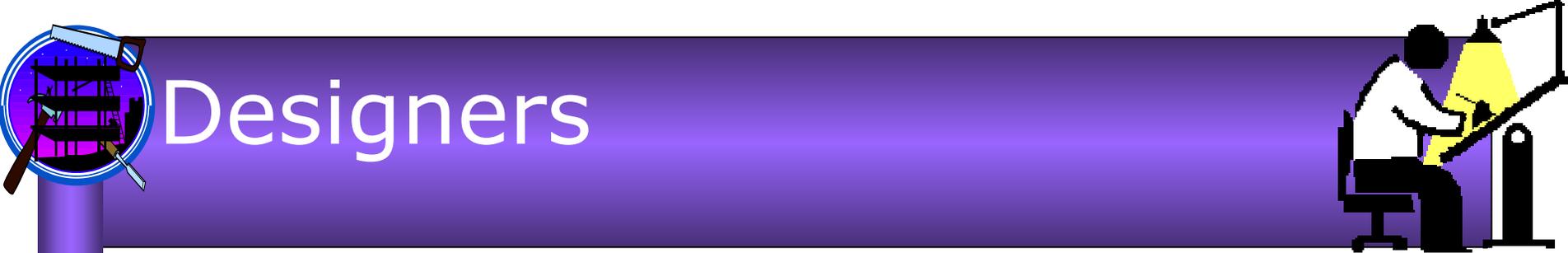
- Non-entrance doors
(mechanical/electrical rooms)
- Vehicle and material handling doors and adjacent personnel doors **OR** revolving doors
- All doors in climates < 1800 HDD65 **OR** in buildings < 4 stories
- All doors that open into spaces < 3000 ft² **OR** into dwelling units



Prescriptive Building Envelope Option (*Section 5.3*)

WWR # 50% of gross wall area
Skylight-roof ratio # 5% of roof area
Each envelope component must separately meet requirements

- 26 criteria sets for different climate types
 - Set = single page that summarizes all prescriptive requirements
 - Insulation levels for roofs, walls floors
 - Fenestration criteria



Designers

- Specify
 - R-values for walls, floors, and roofs
 - U-factors for opaque doors
 - U-factor and SHGC for fenestration**OR**
- Use
 - Pre-calculated assemblies from Appendix A



Opaque Areas (Section 5.3.1)

- Compliance

- Meet or exceed minimum R-values in [table](#)
 - Only R-value of insulation, not to include air films, etc

OR

- Meet maximum U-factor, C-factor, or F-factor for the entire assembly



OR

- Perform area-weighted average U-factor, C-factor, or F-factor
 - Only if there are multiple assemblies within a single class of construction for a single space-conditioning category



Example Table B-13

TABLE B-13

Building Envelope Requirements (HDD65: 3601-5400, CDD50: 3601+)

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-value	Assembly Maximum	Insulation Min. R-value	Assembly Maximum	Insulation Min. R-value
<i>Roofs</i>						
<i>Walls, Above Grade</i>						
<i>Walls, Below Grade</i>						
<i>Floors</i>						
<i>Slab-On-Grade Floors</i>						
<i>Opaque Doors</i>						
Fenestration	Assembly Manx. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Manx. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Manx. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)
Vertical Glazing. % of Wall						
Skylight with Curb, Glass, % of Roof						
Skylight with Curb, Plastic, % of Roof						
Skylight without Curb, All, % of Roof						

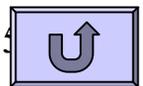
* Exception to 5.3.1.2a applies.





C-factor, F-factor

- C-factor (thermal conductance) – time rate of steady-state heat flow through unit area of a material or construction, induced by a unit temperature difference between the body surfaces. Units of C are $\text{Btu/hft}^2\text{BF}$. Note that C-factor doesn't include soil or air films.
- F-factor – the perimeter heat loss factor for slab-on-grade floors, expressed in $\text{Btu/hft}^2 \text{BF}$





Opaque Areas (*Section 5.3.1*)

- Roof Insulation (*Section 5.3.1.1*)
- Above-Grade Wall Insulation (*Section 5.3.1.2*)
- Below-Grade Wall Insulation (*Section 5.3.1.3*)
- Floor Insulation (*Section 5.3.1.4*)
- Slab-on-Grade Floor Insulation (*Section 5.3.1.5*)
- Opaque Doors (*Section 5.3.1.6*)



Envelope Prescriptive Option

Roof Insulation (*Section 5.3.1.1*)

- Meet or exceed minimum R-value in table
- “Skylight curbs insulated to level of roofs with insulation entirely above deck or R-5, whichever is less”
- Roofs with insulation entirely above deck
 - R-value is for continuous insulation
 - Interruptions for mechanical equipment # 1% of surface of the total roof area





Roof Insulation *(cont'd)*

- Metal building roofs
 - First value is for
 - “insulation draped over purlins and then compressed when metal spanning members attached or
 - insulation hung between purlins provided there’s a min. of 1” thermal break between purlins and metal spanning members
 - Second value is for double-layer installations with insulation installed parallel to the purlins”
- Attics and other roofs
 - R-value is for insulation installed both inside and outside the roof or entirely inside the roof cavity



Above-Grade Wall Insulation

(Section 5.3.1.2)

- Meet or exceed R-value in appropriate table
- Mass walls
 - heat capacity determined from Table A-6 or A-7
 - R-value is for continuous insulation or when uninterrupted by framing other than metal clips no closer than 24 in. o.c. horizontally and 16 in. o.c. vertically
- Exception – requirement of U-0.151



Above-Grade Wall Insulation

(cont'd)



- R-values for
 - **“Metal building wall** = insulation compressed between metal wall panels and the steel structure
 - **Steel-framed wall** = uncompressed insulation installed in the cavity between steel studs
 - **Wood-framed and other** = uncompressed insulation installed in the cavity between wood studs”; also acceptable to be continuous insulation uninterrupted by studs



Below-Grade Wall Insulation (Section 5.3.1.3)



- Meet or exceed values in appropriate table in Appendix B
- R-value is for continuous insulation
- If framing is used, compliance is based on maximum assembly C-factor



Floor Insulation *(Section 5.3.1.4)*

- Meet or exceed values in appropriate table in Appendix B
- R-values for
 - **Mass floors** = continuous insulation; if framing is used, compliance is based on maximum assembly U-factor
 - **Steel joist floors** = uncompressed insulation or spray-on insulation, but is also acceptable for continuous insulation
 - **Wood-framed and others** = uncompressed insulation, but is also acceptable for continuous insulation



Slab-on-Grade Floor Insulation (Section 5.3.1.5)

- Meet or exceed values in appropriate table in Appendix B (includes R-value and depth or width of insulation)
- “Be installed around the perimeter to the distance specified
 - **Inside foundation wall** – extend downward from top of slab a minimum distance specified or to the top of the footing, whichever is less
 - **Outside foundation wall** – extend from top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum distance specified”



Envelope Prescriptive Option

Opaque Doors (*Section 5.3.1.6*)

- Meet or exceed maximum U-factors in appropriate table in Appendix B



Fenestration *(Section 5.3.2)*

- Criteria apply to fenestration, including windows, glass doors, glass block, plastic panels, and skylights
- Compliance
 - Meet or exceed maximum U-factors in table
 - Meet or exceed minimum SHGC in table
 - Use NFRC ratings or default values in Appendix A



Envelope Prescriptive Option

Fenestration (*Section 5.3.2*)

- Fenestration Area
(*Section 5.3.2.1*)
- Fenestration U-Factor
(*Section 5.3.2.2*)
- Fenestration Solar Heat Gain Coefficient
(*Section 5.3.2.3*)
- Visible Light Transmittance
(*Section 5.3.2.4*)



Fenestration Area

(Section 5.3.2.1)

- Total vertical fenestration area to be < 50% of gross wall area
 - including both fixed and operable vertical fenestration
- Total skylight area to be < 5% of gross roof area
 - glass skylights
 - plastic skylights with a curb
 - all skylights without a curb





Fenestration U-Factor (Section 5.3.2.2)

- NFRC or meet or exceed maximum U-factors in A-17
- Exception
 - “Vertical fenestration complying with Exception (c) to 5.3.2.3 to have a U-factor \leq U-factor specified for 40% of the gross wall area”



Fenestration SHGC

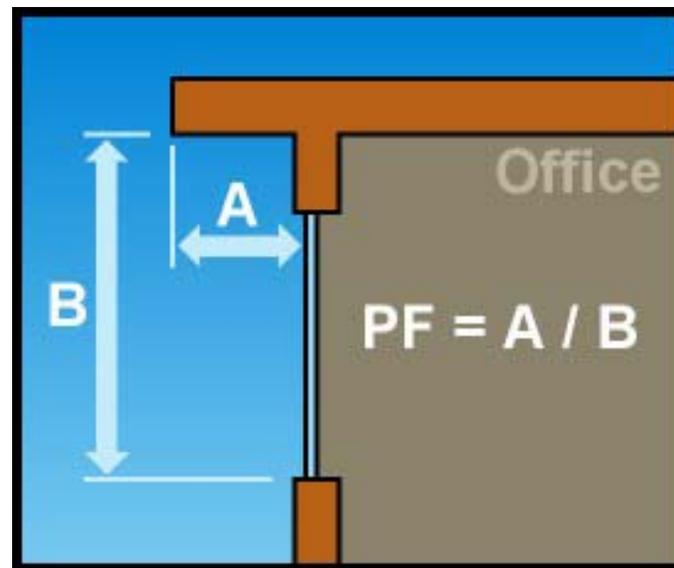
(Section 5.3.2.3)

- Vertical fenestration
 - SHGC values < Table 5.3 (Appendix A-18) for appropriate total vertical fenestration area
- Skylights
 - SHGC values < Table 5.3 (Appendix A-18) for appropriate total skylight area
- “No SHGC requirements for semiheated spaces or for buildings in climates > 10800 HDD65”
- Exceptions



Overhangs

- Standard credits permanent overhangs by adjustment to SHGC
- Size of overhang is determined by projection factor





Visible Light Transmittance

(Section 5.3.2.4)

- No criteria in the Prescriptive Building Envelope Option, but there are “minimum criteria in the Building Envelope Trade-Off Option”



Building Envelope Trade-Off Option (Section 5.4)

Trade-Off
Option

- Building complies if
 - It satisfies the provisions of 5.1 and 5.2
 - $$\frac{\text{EPF}_{\text{Proposed Building}}}{\text{EPF}_{\text{Budget Building}}} \geq 1$$

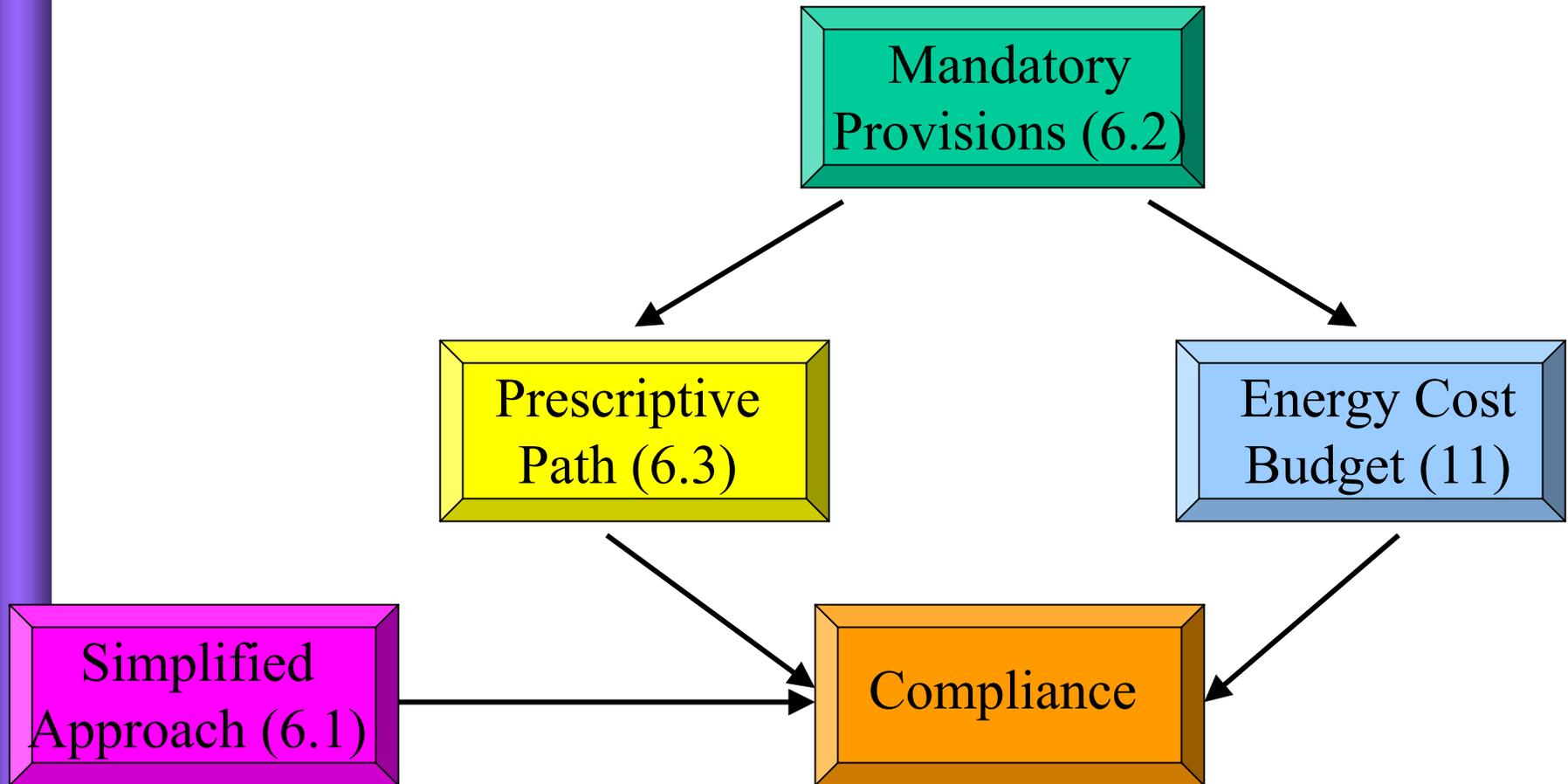
EPF = envelope performance factor

EPF is calculated using Normative Appendix C

"Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems to be the same for proposed building and budget building"



Section 6 - HVAC Compliance





Simplified Approach Option

(Section 6.1)

Simplified
Approach

- Limited to...
 - buildings with 1 or 2 stories
 - buildings $< 25,000\text{ft}^2$
 - single-zone systems
 - air-cooled or evaporatively-cooled only





Simplified *(cont'd)*

- Manual changeover or dual set-point thermostat
- Heat pump supplementary control
- No reheat or simultaneous heating and cooling for humidity control
- Time clocks (except hotel/motel...)
- Pipe and ductwork insulated
- "Ducted system to be air balanced to within 10% of design air flow rates"
- Interlocked thermostats to prevent simultaneous heating and cooling
- Exhausts (design capacity > 300 cfm unless continuous operation)
- Optimum start controls (design supply air capacity > 10,000 cfm)



HVAC Mandatory Provisions

(Section 6.2)

Mandatory Provisions

- Mechanical Equipment Efficiency *(Section 6.2.1)*
- Load Calculations *(Section 6.2.2)*
- Controls *(Section 6.2.3)*
- HVAC System Construction and Insulation *(Section 6.2.4)*
- Completion Requirements *(Section 6.2.5)*

Required in both Prescriptive and ECB compliance paths



Equipment covered

- Package air conditioners
- Heat pumps
- Chillers
- Furnaces
- Boilers
- Heat rejection equipment
- Packaged terminal room air conditioners



Equipment covered for the first time in 90.1-1999

- Ground-source heat pumps
- Single- and double-effect absorption chillers
- Heat rejection equipment
- New categories for
 - hot water and steam boilers
 - replacement PTACs and PTHPs



Mechanical Equipment Efficiency (Section 6.2.1)

- Tables 6.2.1A – 6.2.1G
- Combination systems to meet all requirements for appropriate space heating or cooling category
- “Gas-fired and oil-fired forced air furnaces with input ratings $\geq 225,000$ Btu/h to have intermittent ignition or interrupted device and have either power venting or a flue damper
- All furnaces with input ratings $\geq 225,000$ Btu/h, including electric furnaces, not located in conditioned space, to have jacket losses $\leq 0.75\%$ of the input rating”



Load Calculations

(Section 6.2.2)



- “Determined in accordance with generally accepted engineering standards and handbooks acceptable to the adopting authority”



Controls *(Section 6.2.3)*

- Zone Thermostatic controls *(Section 6.2.3.1)*
 - Required for each zone
 - Dead Band controls
 - Set Point Overlap Restrictions
- Off-Hour controls *(Section 6.2.3.2)*
 - Automatic Shutdown
 - Setback Controls
 - Optimum Start Controls
 - Shutoff Damper Controls
 - Zone Isolation



Controls *(Section 6.2.3)*

- Gravity Vent Controls Ventilation System Controls *(Section 6.2.3.3)*
 - Stair and Shaft Vent dampers
 - Gravity Hoods, Vents, and Ventilator Dampers
- Heat Pump Auxiliary Heat Control *(Section 6.2.3.4)*
- Enclosed Parking Garage Ventilation Controls *(Section 6.2.3.5)* - deleted



Controls *(Section 6.2.3)*

- Humidifier Preheat Controls
(Section 6.2.3.6) *(6.2.3.5)*
- Humidification and Dehumidification Controls
(Section 6.2.3.7) *(6.2.3.6)*
- Freeze Protection and Snow/Ice Melting Systems
(Section 6.2.3.8) *(6.2.3.7)*
- Ventilation Controls for High-Occupancy Areas
(Section 6.2.3.9) *(6.2.3.8)*
- Exceptions



Dead Band *(Section 6.2.3.1.2)*

- Thermostats must have a 5°F dead band
- Exceptions
 - “Thermostats that require manual changeover between heating and cooling modes
 - Special occupancy or applications where wide temperature ranges aren’t acceptable” (e.g., retirement homes) and approved by adopting authority



Set Point Overlap Restriction

(Section 6.2.3.1.3)

- If limit switches, mechanical stops, or software programming for DDC systems are used
 - means will be provided “to prevent the heating set point from exceeding the cooling set point minus any applicable proportional band”



Off-Hour Controls

(Section 6.2.3.2)

- Systems with heating/cooling capacity > 65,000 Btu/h and fan > $\frac{3}{4}$ hp
Shall have the following off-hour controls
 - automatic shutdown
 - setback controls
 - optimum start controls
 - shutoff damper controls
 - zone isolation
- Exceptions, "HVAC systems
 - serving hotel/motel guestrooms
 - intended to operate continuously"



Automatic Shutdown

(Section 6.2.3.2.1)

- Controls to operate on different time schedules for seven different day-types per week and retain programming and time setting during loss of power for at least 10 hrs
- Each control to have
 - occupant sensor, **OR**
 - manually-operated timer with maximum two hour duration, **OR**
 - interlock to security system



Setback Controls

(Section 6.2.3.2.2)

- Applies when heating systems are located where heating design temperature is $\geq 40^{\circ}\text{F}$ and cooling systems located where cooling design temperature $< 100^{\circ}\text{F}$
- "Heating set point adjustable down to $\geq 55^{\circ}\text{F}$ "
- Cooling set point adjustable up to $\leq 90^{\circ}\text{F}$ or to prevent high space humidity levels"
- Exception
 - "Radiant floor and ceiling heating systems"



Optimum Start Controls

(Section 6.2.3.2.3)

- “Individual heating and cooling air distribution systems with
 - total design supply air capacity $> 10,000$ cfm
 - served by one or more supply fans”
- Control algorithm to at least “be a function of
 - difference between space temperature and occupied setpoint and amount of time prior to scheduled occupancy”



Shutoff Damper Controls

(Section 6.2.3.2.4) (6.2.3.3.3)

- Motorized dampers for outdoor air supply and exhaust systems
- "Ventilation outside air dampers to be capable of automatically shutting off during
 - preoccupancy building warm up, cool down, and setback(Except when ventilation reduces energy costs or when ventilation must be supplied to meet code requirements)
- Supply and exhaust dampers to have maximum leakage rate of 3 cfm/ft² at 1.0 in. w.g. when tested in accordance with AMCA Standard 500"



HVAC Mandatory Provisions/Controls Shutoff Damper Controls - Exceptions (Section 6.2.3.2.4) (6.2.3.3.3)

- Gravity dampers okay in buildings
 - < 3 stories in height
 - of any height in climates < 2700 HDD65
- Systems with design outside air intake or exhaust capacity # 300 cfm
 - if “equipped with motor-operated dampers that open and close when unit is energized and de-energized, respectively”



Zone Isolation

(Section 6.2.3.2.5) (6.2.3.2.4)

- Each isolation area
 - Maximum 25,000 ft² zone on one floor
 - Ability to shut off airflow to isolation area
 - Automatic shutdown device
 - Central systems capable of stable operation for smallest isolation area



Stair and Shaft Vents

(Section 6.2.3.3.1)

- Motorized dampers
 - can be “automatically closed during normal building operation
 - interlocked to open as required by fire and smoke detection systems”



HVAC Mandatory Provisions/Controls Gravity Hoods, Vents, and Ventilators (Section 6.2.3.3.2)

- “Motorized dampers to automatically shut when spaces served are not in use”
- Exceptions
 - Gravity dampers okay in buildings
 - < 3 stories in height
 - of any height in climates < 2700 HDD65



HVAC Mandatory Provisions/Controls Heat Pump Auxiliary Heat Control (Section 6.2.3.4)

- Controls to prevent supplementary heat when heat pump can handle the load
 - Exception
 - Heat pumps
 - with minimum efficiency regulated by NAECA
 - with HSPF rating meeting Table 6.2.1B
- ("Includes all usage of internal electric resistance heating")



HVAC Mandatory Provisions/Controls Enclosed Parking Garage Ventilation (Section 6.2.3.5) *Deleted*



- “Garage ventilation fan systems with total design capacity $> 30,000$ cfm” to have at least one automatic control
 - “capable of staging fans or modulating fan volume as required to maintain CO levels below ASHRAE Standard 62” (only applies to garages used predominantly by gasoline-powered vehicles)
 - “complying with 6.2.3.2.1 that’s capable of shutting off fans or reducing fan volume during periods when garage is not in use”



Humidifier Preheat

(Section 6.2.3.6) (6.2.3.5)

- “Automatic valve to shut off preheat when humidification isn’t required”



Humidification and Dehumidification (Section 6.2.3.7) (6.2.3.6)

- Provide means to prevent simultaneous operation of humidification and dehumidification equipment
 - Limit switches, mechanical stops, or software programming (DDC systems)
- Exceptions
 - “Zones served by desiccant systems, used with direct evaporative cooling in series
 - Systems serving zones where specific humidity levels are required and approved by jurisdiction”
 - Computer rooms, museums, and hospitals



HVAC Mandatory Provisions/Controls Freeze Protection and Snow/Ice Melting Systems (*Section 6.2.3.8*) (6.2.3.7)

- Automatic controls for
 - Freeze protection systems
 - “outside air temperatures $> 40^{\circ}\text{F}$ or when conditions of protected fluid will prevent freezing”
 - Snow- and ice-melting systems
 - “pavement temperature $> 50^{\circ}\text{F}$ and no precipitation is falling and outdoor temperature $> 40^{\circ}\text{F}$ ”





HVAC Mandatory Provisions/Controls Ventilation Controls for High-Occupancy Areas (*Section 6.2.3.9*) (6.2.3.8)

- Systems with
 - “design outside air capacities > 3000 cfm and
 - serving areas having an average design occupancy density > 100 people per 1000 ft^2
 - to have means to automatically reduce outside air intake below design rates when spaces are partially occupied
- Ventilation controls in compliance with ASHRAE Standard 62 and local standards
- Exception
 - Systems with heat recovery complying with 6.3.6.1”



HVAC System Construction and Insulation (*Section 6.2.4*)

- General (*Section 6.2.4.1*)
(Section 6.2.4.1.1)
- Duct and Plenum Insulation
(*Section 6.2.4.2*) *(Section 6.2.4.1.2)*
- Duct Sealing (*Section 6.2.4.3*)
(Section 6.2.4.2.1)
- Duct Leakage Tests (*Section 6.2.4.4*)
(Section 6.2.4.2.2)
- Piping Insulation (*Section 6.2.4.5*)
(Section 6.2.4.1.3)



HVAC Mandatory Provisions

General (*Section 6.2.4.1*) (6.2.4.1.1)

- Insulation installed in accordance with industry accepted standards
- Insulation
 - Protected from damage due to sunlight, moisture, equipment maintenance, and wind
 - Exposed to weather to be suitable for outdoor service
 - “Covering chilled water piping, refrigerant suction piping, or cooling ducts located outside the conditioned space to include a vapor retardant located outside the insulation, all penetrations and joints of which to be sealed”



HVAC Mandatory Provisions/HVAC Insulation Duct and Plenum Insulation (Section 6.2.4.2) (6.2.4.1.2)

- All supply and return ducts and plenums to be insulated per Tables 6.2.4.2A and 6.2.4.2B
- Exceptions





Exceptions

- “Factory-installed plenums, casings, or ductwork furnished as part of HVAC equipment
- Ducts or plenums located in heated, semi-heated, or cooled spaces
- For runouts < 10 ft in length to air terminals or air outlets, the R-value need not exceed R-3.5
- Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas > 5 ft² need not exceed R-2; those $\# 5$ ft² need not be insulated”



Duct Sealing

(Section 6.2.4.3) (6.2.4.2.1)

- Table 6.2.4.3A
 - Seal level based on duct type (supply, exhaust, return) and duct location (outdoors, unconditioned spaces, conditioned spaces)
- Table 6.2.4.3B
 - lists sealing requirements based on seal level from Table 6.2.4.3A
- Requirements of 6.2.4.4
- Standard industry practice





Duct Leakage Tests

(Section 6.2.4.4) (6.2.4.2.2)

- Designed > 3 in. w.c.
 - Leak tested
 - Representative sections $\geq 25\%$ of the total installed duct area shall be tested
 - Ratings > 3 in. w.c. to be identified on drawings
 - Maximum permitted duct leakage

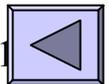




Permitted duct leakage

$$L_{\max} = C_L P^{0.65}$$

Where L_{\max} = maximum permitted leakage in cfm/100 ft² duct surface area"





Piping Insulation

(Section 6.2.4.5) (6.2.4.1.3)

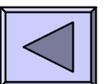
- Table 6.2.4.5
 - Minimum pipe insulation thickness based on fluid design operating temperature range, insulation conductivity, nominal pipe or tube size, and system type (Heating, SWH, Cooling)
- Exceptions
 - Factory-installed
 - Piping conveying fluids
 - “Hot water piping between shut off valve and coil, not > 4 ft in length, when located in conditioned spaces
 - Pipe unions in heating systems (steam, steam condensate, and hot water)”





Fluids

- “design operating temperature range between 60°F-105°F, inclusive”
- that haven’t been heated or cooled through the use of nonrenewable energy or where heat gain or heat loss will not increase energy usage





Completion Requirements

(Section 6.2.5)

- Record drawings
- Operating and maintenance manuals
- System balancing
- System commissioning



HVAC Mandatory Provisions/Completion Req **Drawings** *(Section 6.2.5.1)*



- Record drawings of actual installation to building owner within 90 days of system acceptance and include, as a minimum
 - “Location and performance data on each piece of equipment
 - General configuration of duct and pipe distribution system including sizes
 - Terminal air or water design flow rates”



HVAC Mandatory Provisions/Completion Req **Manuals** (*Section 6.2.5.2*)



- Operating and maintenance manuals to building owner within 90 days of system acceptance and include, as a minimum



System Balancing

(Section 6.2.5.3.1)



- Measured and adjusted within 10% of design rates
 - Exception
 - “Variable speed, variable volume flow distribution systems need not be balanced upstream of a pressure independent device”
- Written report for conditioned spaces > 5000 ft²



Air System Balancing

(Section 6.2.5.3.2)

- Minimize throttling losses
- For fans with system power > 1 hp
 - Adjust fan speed to meet design flow conditions
 - “variable flow distribution systems need not be balanced upstream of the controlling device”



Hydronic System Balancing

(Section 6.2.5.3.3)

- Proportionately balanced to minimize throttling losses
- “Pump impeller trimmed or pump speed adjusted to meet design flow conditions”
- Each system to have either “the ability to measure differential pressure increase across the pump or have test ports at each side of the pump”
- Exceptions





Exceptions

- “Pumps with pump motors # 10 hp
- When throttling results in $< 5\%$ of the nameplate hp draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed”



System Commissioning

(Section 6.2.5.4)

- “Control elements are calibrated, adjusted, and in proper working condition”
- > 50,000 ft² conditioned area
 - Except warehouses and semiheated spaces
 - Requires commissioning plan



HVAC Prescriptive Path

(Section 6.3)

Prescriptive
Path

- Economizers *(Section 6.3.1)*
- Simultaneous Heating and Cooling Limitation *(Section 6.3.2)*
- Air System Design and Control *(Section 6.3.3)*
- Hydronic System Design and Control *(Section 6.3.4)*
- Heat Rejection Equipment *(Section 6.3.5)*
- Energy Recovery *(Section 6.3.6)*
- Exhaust Hoods *(Section 6.3.7)*
- Radiant Heating Systems *(Section 6.3.8)*
- Hot Gas Bypass Limitation *(Section 6.3.9)*



Economizers (*Section 6.3.1*)

Prescriptive
Path

- Air Economizers (*Section 6.3.1.1*)
 - Design Capacity
 - Control Signal
 - High Limit Shutoff
 - Dampers
 - Relief of Excess Outside Air
- Water Economizers (*Section 6.3.1.2*)
 - Design Capacity
 - Maximum Pressure Drop
- Integrated Economizer Control (*Section 6.3.1.3*)
- Economizer Heating System Impact (*Section 6.3.1.4*)



Economizers (*Section 6.3.1*)

- Climate and size dependent (Table 6.3.1)
- There are LOTS of exceptions
- Can use air economizers
 - 100% of design supply air
 - Sequenced with mechanical cooling equipment
 - High limit shutoff
 - Dampers
- Can use water economizers
 - 100% of expected system cooling load
 - Maximum pressure drop



Design Capacity (*Section 6.3.1.1.1*)

- “System capable of modulating outside air and return air dampers to provide up to 100% of the design supply air quantity as outside air for cooling”



Control Signal (*Section 6.3.1.1.2*)

- “Dampers capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature”
- Exception
 - “Systems controlled from space temperature (such as single-zone systems)”



High Limit Shutoff (*Section 6.3.1.1.3*)

- Automatically reduce outside air intake to “6.1.2 of ASHRAE Standard 62 when outside air intake will no longer reduce cooling energy usage”
- Control types for specific climates from Table 6.3.1.1.3A
- Settings from Table 6.3.1.1.3B



Dampers (*Section 6.3.1.1.4*)

- Return air and outside air dampers to have maximum leakage rate of 20 cfm
- Return air and outside air dampers to meet the damper leakage specified in 6.2.3.3.4 (Table 6-B)



Relief of Excess Outside Air (Section 6.3.1.1.5)

- “Means to relieve excess outdoor air during economizer operation to prevent overpressurizing the building
- Outlet located to avoid recirculation into the building”



Design Capacity (*Section 6.3.1.2.1*)

- System capable of
 - cooling supply air by indirect evaporation and
 - “providing up to 100% of expected system cooling load at outside air temperatures of 50°F dry bulb/45°F wet bulb and below”
- Exception
 - or meet “100% of expected cooling load at 45°F dry bulb/40°F wet bulb”



Maximum Pressure Drop (Section 6.3.1.2.2)

- Precooling coils and water-to-water heat exchangers to have either
 - Water-side pressure drop of < 15 ft of water **OR**
 - Create a secondary loop so the coil or “heat exchanger pressure drop isn’t seen by the circulating pumps when the system is in normal cooling mode”



Integrated Economizer Control

(Section 6.3.1.3)

- Economizers must be “integrated with mechanical cooling systems and be capable of providing partial cooling even when additional mechanical cooling is required”
- Some exceptions to this



Economizer Heating System Impact (Section 6.3.1.4)

- Designed so economizer operation “doesn’t increase the building heating energy use during normal operation”
- Exception
 - Where heating is allowed by 6.3.2



Simultaneous Heating and Cooling Limitation *(Section 6.3.2)*

- Zone Controls *(Section 6.3.2.1)*
- Hydronic System Controls *(Section 6.3.2.2)*
 - Three-Pipe System
 - Two-Pipe Changeover System
 - Hydronic (Water Loop) Heat Pump Systems
- Dehumidification *(Section 6.3.2.3)*
- Humidification *(Section 6.3.2.4)*



Simultaneous Heating and Cooling Limitation (*Section 6.3.2*)

- Zone controls capable of operating in sequence the supply of heating and cooling energy to the zone to prevent
 - reheating,
 - recooling,
 - mixing, or
 - simultaneously supplying air previously heated or cooled
- Hydronic system controls to prevent reheating or recooling of fluids



Simultaneous Heating and Cooling Limitation *(cont'd)*

- Dehumidification controls for humidistats to prevent reheating, mixing, etc
- Humidification controls



Zone Controls (*Section 6.3.2.1*)

- Capable of operating in sequence the supply of heating and cooling energy to the zone
- Controls prevent
 - Reheating
 - Recooling
 - Mixing or simultaneously supplying air previously heated or cooled
 - Other simultaneous operation of heating and cooling systems to the same zone
- Exceptions





Zone Controls - Exceptions

- “Zones for which volume of air that is reheated, recooled, or mixed is no greater than the larger of the following
 - Volume of outside air to meet 6.1.3 of ASHRAE 62 for the zone
 - 0.4 cfm/ft² of zone conditioned floor area with several conditions
 - 30% of zone design peak supply
 - 300 cfm for zones whose peak flow rate totals no more than 10% of the total fan system flow rate
 - Any higher rate that can be demonstrated to jurisdiction to reduce overall system annual energy usage...
- Zones where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that the variable air volume systems are impractical
- Zones where at least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site solar energy source”





HVAC Prescriptive Path

Hydronic System Controls

(Section 6.3.2.2)

- Limit heating and cooling of fluids previously heated or cooled mechanically per 6.3.2.2.1 and 6.3.2.2.3



HVAC Prescriptive Path

Three-Pipe System

(Section 6.3.2.2.1)

- No common return system for both hot and chilled water



Two-Pipe Changeover System (Section 6.3.2.2.2)

- Common distribution system acceptable if
 - deadband from one mode to another is $\pm 15^{\circ}\text{F}$ outside air temperature
 - controls to allow operation of ± 4 hours before changing over
 - reset controls so heating and cooling supply temperatures at changeover point no more than 30°F apart



Hydronic (Water Loop) Heat Pump Systems (*Section 6.3.2.2.3*)

- Controls to provide “heat pump water supply temperature deadband of at least 20°F between initiation of heat rejection and heat addition by central devices”
- Cooling tower bypass or cooling tower isolation dampers
- “A two-position valve at each hydronic heat pump for hydronic systems having a total pump system power > 10 hp”
- Exception
 - If system loop temperature optimization controller is used, deadband < 20°F is allowed



Dehumidification (*Section 6.3.2.3*)

- Humidistatic controls to prevent
 - Reheating
 - Mixing of hot and cold air streams
 - Heating and cooling of same air stream
- Exceptions





Dehumidification exceptions

- Systems
 - capable of reducing supply air flow to 50%, or to minimum ventilation
 - under 6.67 tons that can unload at least 50%
 - smaller than 3.3 tons
- Process applications
- 75% of reheat or recool energy is recovered or solar



Humidification (*Section 6.3.2.4*)

- “Systems with hydronic cooling and humidification systems designed to maintain inside humidity at $> 35^{\circ}\text{F}$ dewpoint temperature shall use a water economizer if required by 6.3.1”



Air System Design and Control (Section 6.3.3)

- Fan Power Limitation
(Section 6.3.3.1)
- Variable Air Volume Fan Control
(Section 6.3.3.2)
 - Part-Load Fan Power Limitation
 - Static Pressure Sensor Location
 - Set Point Reset



HVAC Prescriptive Path

Air System Design and Control (Section 6.3.3)

- HVAC systems with total fan system power > 5 hp to meet 6.3.3.1 and 6.3.3.2
 - Fan Power Limitation
 - VAV Fan Control



Fan Power Limitation

(Section 6.3.3.1)

- Table 6.3.3.1
 - By supply air volume and allowable nameplate motor power (constant volume and variable volume)
- Allowable fan system power may be adjusted in certain situations



Part-Load Fan Power Limitation (Section 6.3.3.2.1)

- Individual VAV fans with motors
\$30 hp
 - “Have other controls and devices to result in fan motor demand \leq 30% of design wattage at 50% of design air volume when static pressure set point = $1/3$ of total design static pressure, based on manufacturer’s certified fan data”



Static Pressure Sensor Location (Section 6.3.3.2.2)

- Placed so controller set point is # 1/3 the total design fan static pressure
 - Except for digital control systems with zone reset capabilities where it may be at the fan discharge
- If this results in the sensor being located downstream of major duct splits, install multiple sensors in each major branch



Set Point Reset

(Section 6.3.3.2.3)

- “For systems with direct digital control of individual zone boxes reporting to the central control panel
 - Static pressure set point reset based on zone requiring the most pressure”



Hydronic System Design and Control *(Section 6.3.4)*

- Hydronic Variable Flow Systems *(Section 6.3.4.1)*
- Pump Isolation *(Section 6.3.4.2)*
- Chilled and Hot Water Temperature Reset Controls *(Section 6.3.4.3)*
- Hydronic (Water-Loop) Heat Pump Systems *(Section 6.3.4.4)*



Hydronic System Design and Control *(Section 6.3.4)*

- “HVAC hydronic systems with total pump system power > 10 hp shall meet 6.3.4.1 – 6.3.4.4”
 - Hydronic Variable Flow Systems
 - Pump Isolation
 - Chilled and Hot Water Temperature Reset
 - Hydronic (Water-Loop) Heat Pump Systems



Hydronic Variable Flow

(Section 6.3.4.1)

- HVAC pumping systems to include control valves
 - Designed to modulate or step open and close as a function of load
 - Designed for variable fluid flow
 - Capable of reducing flow rates to # 50% of design flow rate
- “Individual pumps serving variable flow systems with a pump head > 100 ft and motor > 50 hp
 - Have controls and/or devices resulting in pump motor demand # 30% of design wattage at 50% of design water flow”



Hydronic Variable Flow – Exceptions

- Systems where
 - “Minimum flow is $<$ minimum flow required by equipment manufacturer for proper operation of equipment served by the system”
 - Total pump system power $\#$ 75 hp
- Systems that include $\#$ 3 control valves



Pump Isolation (*Section 6.3.4.2*)

- If chilled water plant has more than one chiller or boiler plant has more than one boiler
 - Provide for flow reduction when chiller or boiler is shut down



Chilled and Hot Water Temperature Reset Controls (*Section 6.3.4.3*)

- Affects systems with design capacity > 300,000 Btu/h
 - “To include controls to automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature”
- Exceptions
 - Would result in improper operation
 - Hydronic systems with variable flow



Hydronic (Water-Loop) Heat Pump Systems (Section 6.3.4.4)

- For heat pump loops with total pump system power > 10 hp
 - Two-position valves at each hydronic heat pump must be provided and interlocked to shut off water flow to the heat pump when the compressor is off
 - This basically converts the system into a variable flow system. As such, these systems must also comply with 6.3.4.1



Heat Rejection Equipment (Section 6.3.5)

- “Applies to heat rejection equipment used in comfort cooling systems such as
 - air-cooled condensers
 - open cooling towers
 - closed-circuit cooling towers
 - evaporative condensers
- Exceptions
 - Heat rejection devices included as an integral part of equipment listed devices whose energy usage is included in Tables 6.2.1A-6.2.1D”



Fan Speed Control *(Section 6.3.5.2)*

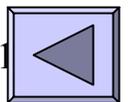
- Each fan powered by a motor ≥ 7.5 hp have
 - capability to operate fan at $\geq 2/3$ full speed
 - “controls to automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device”
- Exceptions





Exceptions

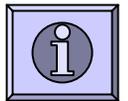
- Condenser fans serving multiple refrigerant circuits or flooded condensers
- Installations located in climates > 7200 CDD50
- 1/3 of the fans on a multiple fan application speed controlled





Exhaust Air Energy Recovery (Section 6.3.6.1)

- Incorporate exhaust air energy recovery in systems with
 - 70% outside air and 5000 cfm total
 - 50% energy recovery effectiveness
- Exceptions





Exceptions

- Lab systems meeting 6.3.7.2
- Systems
 - “serving uncooled spaces that are heated to $< 60^{\circ}\text{F}$ ”
 - exhausting toxic, flammable, paint or corrosive fumes or dust”
 - Requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil
- “Commercial kitchen hoods classified as Type 1 by NFPA 96
- Where $> 60\%$ of outdoor heating energy is provided from site-recovered or site solar energy
- Heating systems in climates < 3600 HDD65
- Cooling systems in climates with a 2.5% cooling design wet-bulb temperature $< 65^{\circ}\text{F}$
- Where largest exhaust source is $< 75\%$ of the design outdoor airflow”





Heat Recovery for Service Water Heating (*Section 6.3.6.2*)

- Condenser recovery required if
 - 24 hrs per day **and**
 - heat rejection $> 6,000,000$ Btu/h **and**
 - SWH load $> 1,000,000$ Btu/h



Kitchen Hoods (Exhaust)

(Section 6.3.7.1)

- Hoods > 5000 cfm to be “provided with makeup air sized for at least 50% of exhaust air volume that is a) unheated or heated to more than 60°F and b) uncooled or cooled without the use of mechanical cooling
- Exceptions
 - Where hoods are used to exhaust ventilation air that would otherwise exfiltrate or be exhausted by other fan systems
 - Certified grease extractor hoods that require a face velocity no greater than 60 fpm”



Fume Hoods (Exhaust)

(Section 6.3.7.2)

- Hood systems with a total exhaust rate > 15,000 cfm to have ONE of the following features
 - Operation to < 50% design flow **OR**
 - Direct make up at least 75% of exhaust rate at specified conditions **OR**
 - Heat recovery for make-up air



HVAC Prescriptive Path

Radiant Heating Systems

(Section 6.3.8)

- Required for unenclosed spaces except loading docks with air curtains
- “Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard”



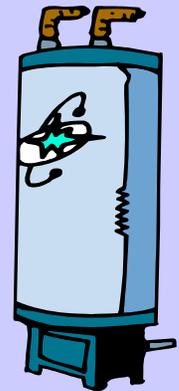
Hot Gas Bypass Limitation (Section 6.3.9)

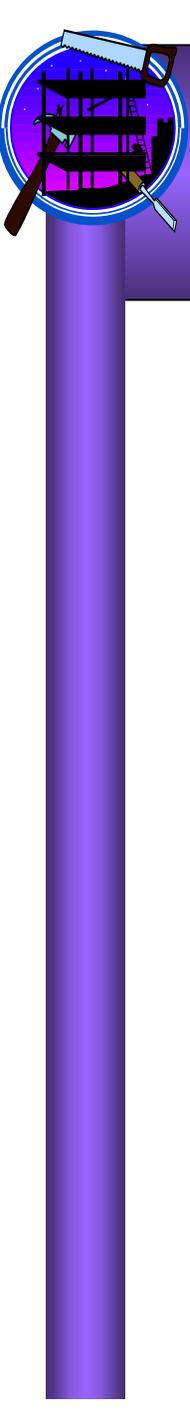
- Not used (including other evaporator pressure control systems) “unless system is designed with multiple steps of unloading or continuous capacity modulation”
- Exception
 - “Unitary packaged systems with cooling capacities \leq 90,000 Btu/h”



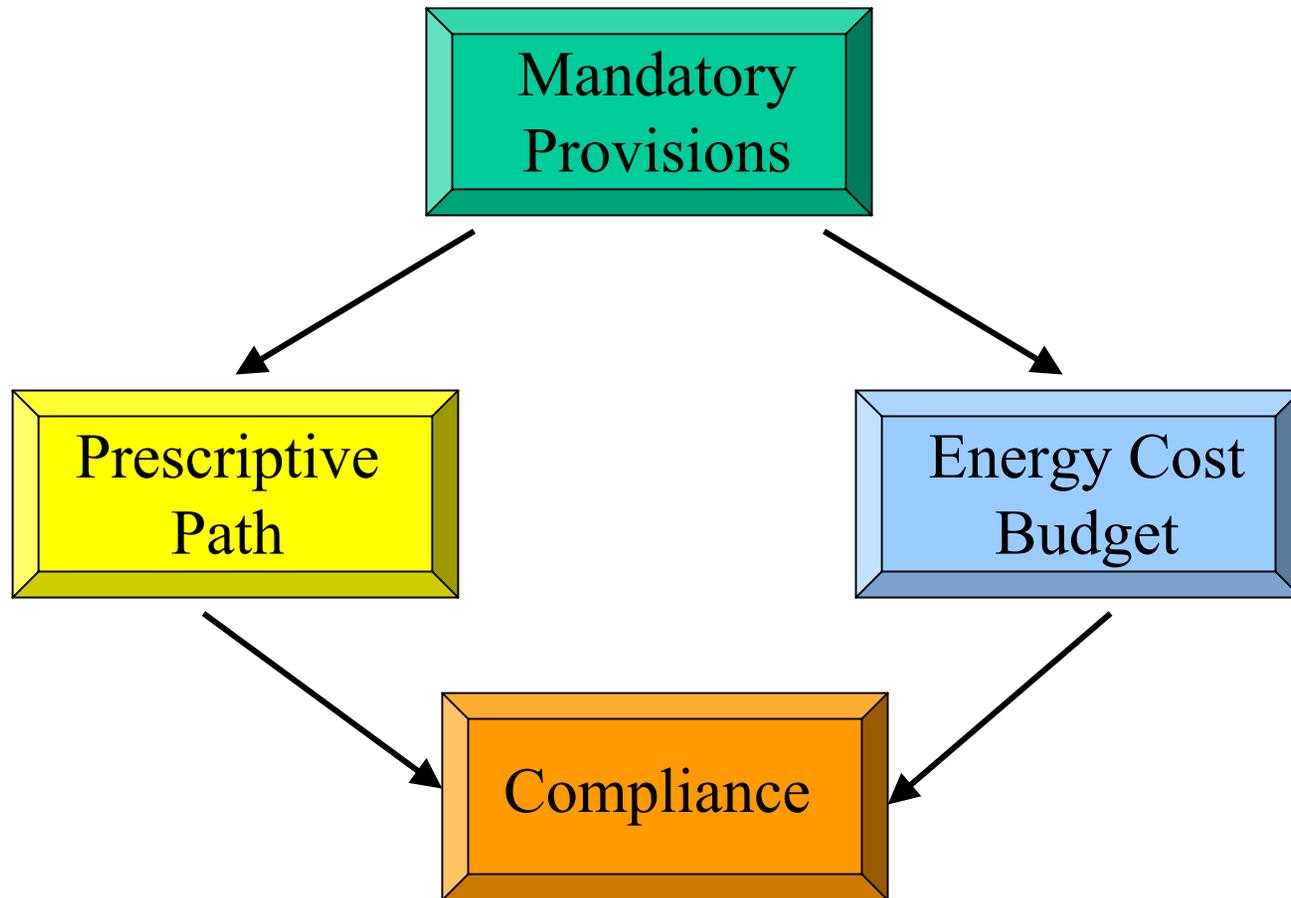
Section 7 - Service Water Heating

- General (*Section 7.1*)
- Mandatory Provisions (*Section 7.2*)
 - Sizing of systems Load Calculations
 - Equipment efficiency
 - Service hot water piping insulation
 - System controls
 - Pools
 - Heat traps
 - Space heating and water heating
 - Service water heating equipment
- Prescriptive Path (*Section 7.3*)





SWH Compliance (*Section 7.1.2*)



Mandatory Provisions

- In accordance with manufacturer's published sizing guidelines or generally accepted engineering standards and handbooks



Equipment Efficiency

(Section 7.2.2)

- Table 7.2.2
- Equipment not listed in Table 7.2.2 has no minimum performance requirements
- Exception





Exception

- Water heaters and hot water supply boilers > 140 gal storage capacity don't "have to meet standby loss requirements when
 - tank surface is thermally insulated to R-12.5, **and**
 - a standing pilot light isn't installed, **and**
 - gas- or oil-fired water heaters have a flue damper or fan-assisted combustion"



Service Hot Water Piping Insulation (*Section 7.2.3*)

- Table 6.2.4.5, Section 6
- Circulating water heater
 - Recirculating system piping, including supply and return piping
- Nonrecirculating storage system
 - First 8 ft of outlet piping
 - Inlet pipe between storage tank and heat trap
- Externally-heated pipes (heat trace or impedance heating)



System Controls *(Section 7.2.4)*

- Temperature Controls
(Section 7.2.4.1)
- Temperature Maintenance Controls
(Section 7.2.4.2)
- Outlet Temperature Controls
(Section 7.2.4.3)
- Circulating Pump Controls
(Section 7.2.4.4)



Temperature Controls

(Section 7.2.4.1)

- To “allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use
- Exception
 - If manufacturer’s installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion”



Temperature Maintenance Controls *(Section 7.2.4.2)*

- Automatic time switches or other controls
 - “Set to switch off usage temperature maintenance system during extended periods when hot water is not required”



Outlet Temperature Controls (Section 7.2.4.3)

- Automatic time switches or other controls
 - To limit maximum temperature of water in faucets in public facility restrooms to 110°F



Circulating Pump Controls (Section 7.2.4.4)

- To limit operation to “a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle”



Pools *(Section 7.2.5)*



- Pool heaters to have readily accessible on-off switch
- Pool heaters fired by natural gas to NOT have continuously burning pilot lights
- Vapor retardant pool covers required (unless recovered or solar heat)
- Time switches required





Heat Traps (*Section 7.2.6*)

- Noncirculating systems to have heat traps on both the inlet and outlet piping as close as practical to storage tank (if no integral heat traps)
 - Either a device specifically designed for this purpose or
 - “Arrangement of tubing that forms a loop of 360° or piping that form the point of connection to the water heater includes a length of piping directed downward before connection to the vertical piping of the supply water or hot water distribution system, as applicable”



Space Heating and Water Heating *(Section 7.3.1)*

Prescriptive
Path

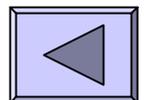
- “Gas- or oil-fired space heating boiler system (complying with Section 6) is allowed to provide total space heating and water heating when **ONE** of the following conditions is met”
 - Single boiler or component that is heating the service water has a certain standby loss in Btu/h
 - Jurisdiction agrees use of a single heat source will consume less energy than separate units
 - Energy input of the combined boiler and water heater system is $< 150,000$ Btu/h
- Instructions for determining standby loss are included in this Section





Standby loss equation

- Standby loss not exceeding
 - $(13.3 \times pmd + 400) / n$; where pmd is probable maximum demand in gal/h and n is the fraction of the year when outdoor daily mean temperature is $> 64.9^{\circ}\text{F}$





SWH/Prescriptive Path

Service Water Heating Equipment (*Section 7.3.2*)

- “Equipment used to provide the additional function of space heating as part of a combination (integrated) system shall satisfy all requirements for service water heating equipment”



Section 8 - Power

Mandatory Provisions

- Voltage drop
- Completion requirements



Voltage Drop

(Section 8.2.1)



- Two types of conductors
 - Feeder conductors
 - Run between the service entrance equipment and the branch circuit distribution equipment
 - 2% maximum voltage drop allowed
 - Branch circuit conductors
 - Run from the final circuit breaker to the outlet or load
 - 3% maximum voltage drop allowed



Completion Requirements

(Section 8.2.2)

- Owner gets information about the building's electrical system
 - Record drawings of actual installation within 30 days
 - Manuals





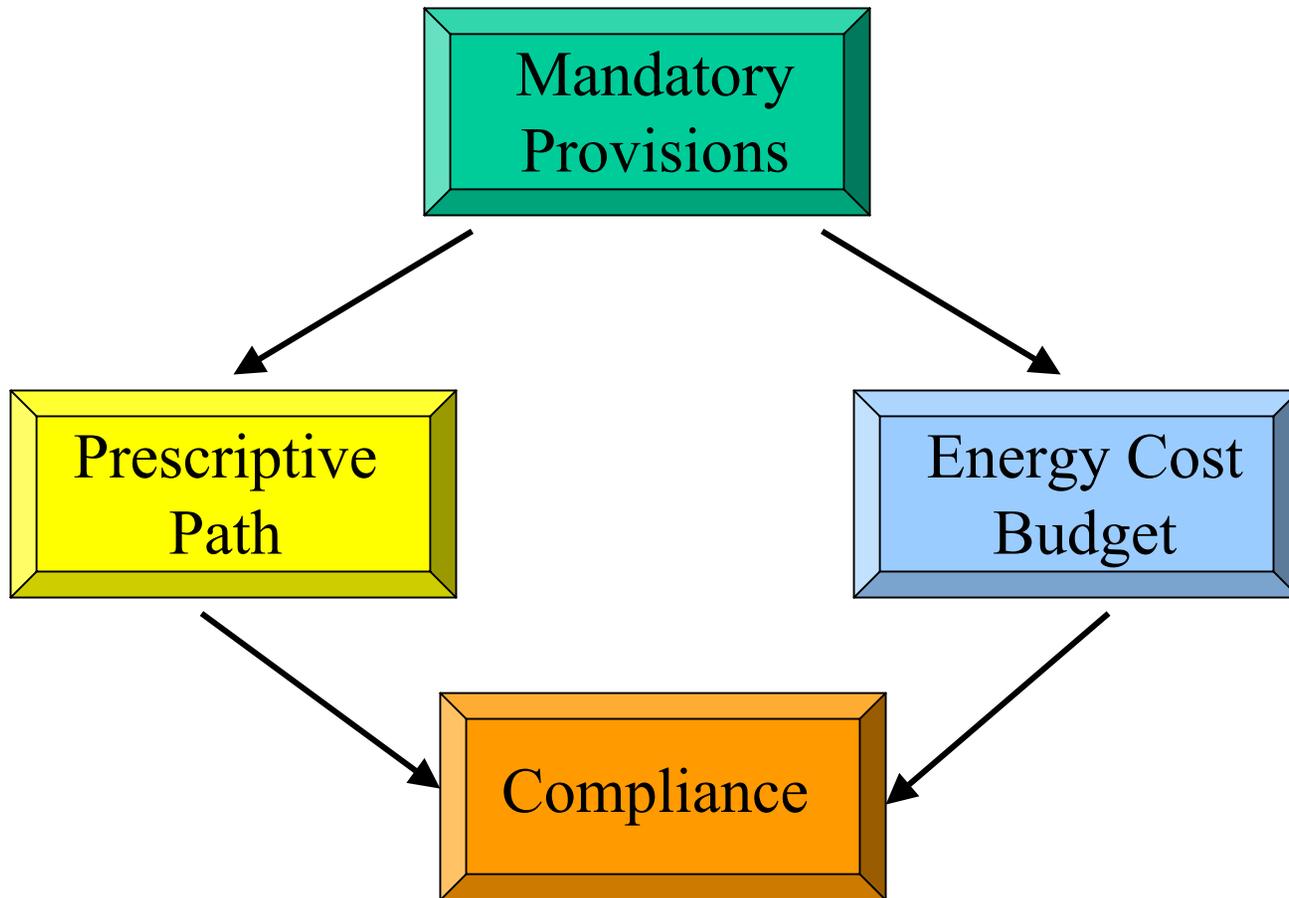
Section 9 - Lighting

- General Application (*Section 9.1*)
- Mandatory Provisions (*Section 9.2*)
 - Lighting controls
 - Tandem wiring
 - Exit signs
 - Installed interior lighting power
 - Luminaire wattage
 - Exterior building grounds lighting
- Prescriptive Path (*Section 9.3*)
 - Interior Lighting Power Allowance
 - Building Area Method
 - Space-by-Space Method
 - Exterior Lighting Power Allowance





Lighting compliance





Lighting general application

- Interior spaces of buildings
- Exterior building features
- Exterior grounds lighting powered through building
- Exceptions
 - Emergency lighting
 - Lighting required by life safety statute
 - Lighting within living units of buildings
 - Decorative gas lighting



Lighting changes between 90.1-1989 and 90.1-2001

- More efficient lighting
 - Less power allowed
- No lighting control credits
 - Lighting power allowance now based only on connected lighting power
- No control points for spaces
- No separate lighting controls for daylighted spaces



Lighting changes between 90.1-1989 and 90.1-2001 *(cont'd)*

- Automatic shutoff controls required
- Most exterior power requirements replaced with minimum efficacy requirements
 - Parking garages included in interior lighting
- Interior power requirements updated
 - More stringent requirements
 - Area factors no longer need to be calculated
 - Building area allowances no longer depend on size
- Additional power allowances for certain specialty lighting



Lighting scope

- New construction
- Existing nonresidential and high-rise residential
 - If \$ 50% of existing luminaires are replaced
 - If renovation increases lighting power
- Control must be readily accessible and located so occupants can see the controlled lighting



Lighting Control *(Section 9.2.1)*

Mandatory
Provisions

- Automatic Lighting Shutoff
(Section 9.2.1.1)
- Space Control *(Section 9.2.1.2)*
- Exterior Lighting Control
(Section 9.2.1.3)
- Additional Control
(Section 9.2.1.4)



Automatic Lighting Shutoff (Section 9.2.1.1)



Mandatory
Provisions

- Applies to buildings $> 5000 \text{ ft}^2$
 - Time-scheduling devices that accommodate separate schedules for each floor or each space $> 25,000 \text{ ft}^2$ **OR**
 - Occupant-sensing devices that turn off lights in each controlled space within 30 minutes of last occupant detection **OR**
 - Signal from another control or alarm system that indicates area is unoccupied



Space Control *(Section 9.2.1.2)*

- At least one for each room or space enclosed by ceiling-height partitions
- Readily accessible to occupants
 - Except for safety or security
- In spaces $\leq 10,000$ ft², each control can serve a maximum of 2500 ft²
- In spaces $> 10,000$ ft², each control can serve a maximum of 10,000 ft²



Exterior Lighting Control

(Section 9.2.1.3)

- Photocells or astronomical time switch required
- Seven-day electrically-driven, mechanical clocks with trippers, astronomical dial, and four-hour spring-wound storage
- Seven-day or calendar year, electronic programmable time switches with astronomic correction and battery backup
- Any of the timers above with a photocell (in place of astronomical correction)
- Exceptions – lighting for
 - Covered vehicle entrances
 - Exits from buildings or parking structures(where required for safety, security, or eye adaptation)



Additional Control

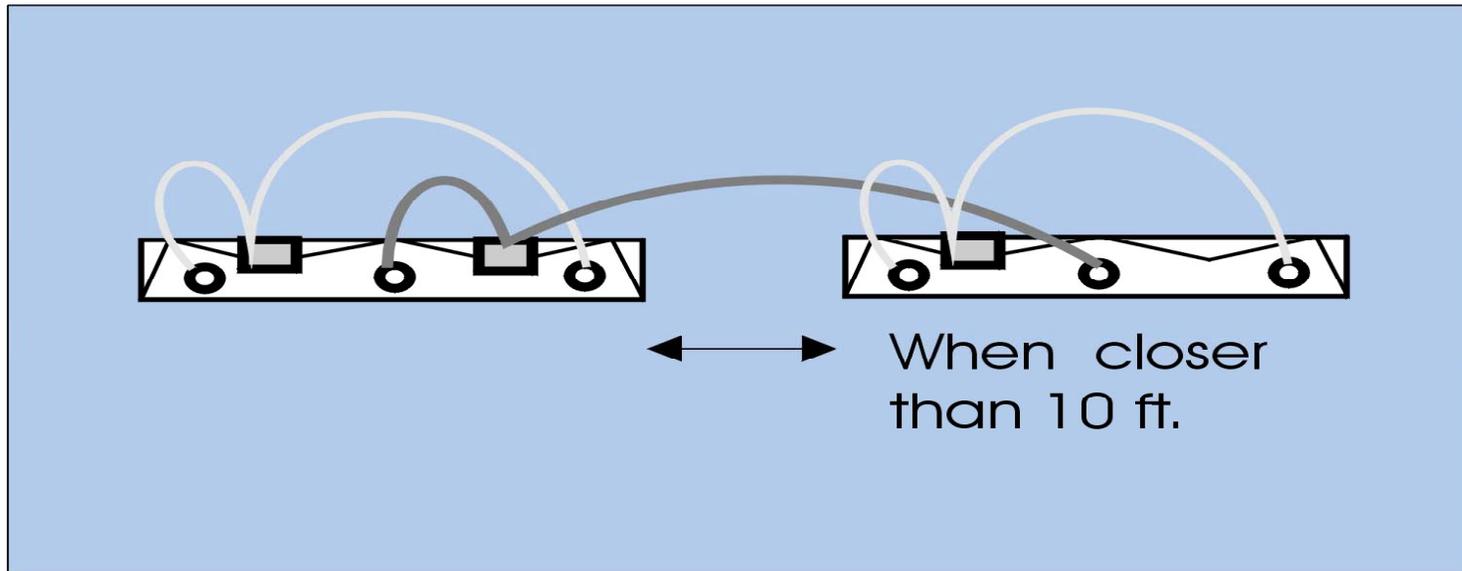
(Section 9.2.1.4)

- Many special lighting applications must be controlled separately
 - Display/accent lighting
 - Case lighting
 - Hotel/motel guest room lighting
 - Task lighting
 - Nonvisual lighting
 - Demonstration lighting



Lighting Mandatory Provisions

Tandem Wiring (Section 9.2.2)





Tandem Wiring Exceptions

(Section 9.2.2)

- Separated surface or pendant luminaires
- Recessed luminaires more than 10 ft apart
- Other luminaires
 - With three-lamp ballasts
 - On emergency lighting circuits
 - With no available pair
 - With one lamp, high frequency, electronic ballast



- Exit signs operating at > 20 W must have a source efficacy ≥ 35 lumens/W
- LED lamps okay
- CF lamps with electronic ballasts usually okay
- Majority of incandescent lamps not okay



Efficacy

- The ratio of light output to watts input
 - lumens per watt
- The higher the efficacy, the more efficient the light source
 - 40 watt incandescent = 480 lumens
 - 40 watt fluorescent = 2640 lumens



Installed Interior Lighting Power (Section 9.2.4)

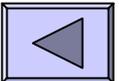
- Includes all permanent and portable interior lighting intended for general, ambient, or task illumination
- Includes lamp, power used by ballast, the control (when applicable), current regulators, and any other power draws associated with the lighting system
- Exception





Exception

- “If 2 or more independently operating lighting systems in a space can be controlled to prevent simultaneous operation, can base IILP on lighting system with highest wattage”





Luminaire Wattage

(Section 9.2.5)



- Standard incandescent = max. labeled wattage of the luminaire
- Luminaires with ballasts = wattage of the lamp/ballast combination
- Line voltage track = min. 30 W per foot
- Low voltage track = transformer wattage
- All others as specified



Lighting power development concept

- Create building space models to calculate power densities with:
 - Current product performance data
 - Updated efficacy and loss factors
 - New building construction data
 - IES-recommended light levels
 - Professional lighting design consensus



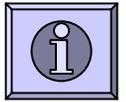
Exterior Building Grounds Lighting (*Section 9.2.6*)

- Luminaires that operate at $> 100 \text{ W} =$
efficacy $> 60 \text{ lumens/W}$
- Exceptions
 - Traffic signals
 - Lighting within outdoor signs
 - Lighting used to illuminate public
monuments or registered historic landmarks
 - If an occupancy sensor or motion sensor
controls the lighting application



Interior Lighting Power

Prescriptive
Path



- Lots of exemptions
- Calculation methods
 - Building area
 - Space-by-space
 - Trade-offs of interior lighting power allowance among portions of the building for which a different calculation method has been used is not permitted



Lighting power allowance exemptions

- Theatrical, stage, film, and video production
- Medical and dental procedures
- Exhibit displays for museums monuments, and galleries
- Plant growth or maintenance
- Integral to equipment or instrumentation installed by manufacturer
- Integral to both open and glass-enclosed refrigerator and freezer cases
- Retail display windows, provided the display is enclosed by ceiling-height partitions
- Interior spaces specifically designated as registered interior historic landmarks
- Integral part of advertising or directional signage
- Exit signs
- Sale or lighting educational demonstration systems
- Athletic playing areas with permanent facilities for TV broadcasting
- Casino gaming areas
- For use in areas specifically designed for the visually impaired



Building Area Method

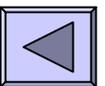
(Section 9.3.1.1)

- Used for projects involving
 - An entire building
 - A single, independent, and separate occupancy in a multi-occupancy building
- Gross lighted area is multiplied by allowance from Table 9.3.1.1
- Limitations
 - Insensitive to specific space functions and room configurations
 - Generally is more restrictive
 - Does not apply to all building types - but “selection of a reasonably equivalent type” is permitted



Gross lighted area

- Sum of total lighted area of a building
 - Measured from the exterior faces of the exterior walls or from the centerline of walls separating buildings
- Used in the building area method of determining interior lighting power allowance





Building area allowances

- Table 9.3.1.1 – here's a sample

Building Type	Lighting Power Density (W/ft²)
Automotive Facility	1.5
Convention Center	1.4
Court House	1.4
Dining: Bar Lounge/Leisure	1.5
Dining: Cafeteria/Fast Food	1.8
Dining: Family	1.9
	1.5



Space-by-Space Method

(Section 9.3.1.2)

- Identify different building types in your project
- Divide gross lighted area of the building into each of the space types
- Calculate lighting power allowance by multiplying area of space type by lighting power density for that specific space type
- Sum all the allowances
- Advantages
 - More flexible
 - Applicable to all building types
 - Accounts for room geometry (e.g., lighting needs of enclosed office vs. open office)



Additional Interior Lighting Power *(Section 9.3.1.2.1)*

- An increase in the ILPA is allowed for specific space functions when using the space-by-space method
 - Decorative – 1.0 W/ft² in space used
 - Fluorescent designed to eliminate glare - .35 W/ft²
 - Lighting equipment installed in retail spaces specifically to highlight merchandise in specific space used
 - Additional 1.6 W/ft² times the area of specific display, or
 - Additional 3.9 W/ft² times the area of specific display for fine merchandise



Exterior Building Lighting Power (Section 9.3.2)

- Sum of all lighting power allowances for applicable exterior applications
- Building Surface Requirements
 - Building entrance with canopy – 3 W/ft²
 - Building entrance – 33 W/linear ft
 - Building exit – 20 W/linear ft
 - Building facades – 0.25 W/ft²
- Exceptions, when equipped with a control device





Exceptions

- When equipped with a control device
 - Specialized signal, directional, and market lighting associated with transportation
 - Public monuments
 - Registered historic landmark structures or buildings
 - Lighting integral to advertising signage



Section 10 - Other Equipment

- Changes between 90.1-1989 and 90.1-1999
 - No transformer recommendations and requirements
 - No subdivision of electrical feeders or provisions for check metering
 - *Motor efficiency levels are higher and correspond to EPC Act (only requirement in this section)*
 - Motor efficiency requirement now covers all relevant motors, even if they're part of equipment rated elsewhere in the Standard
 - No exemption for motors running < 1000 hrs/yr



Section 11 - Energy Cost Budget Method



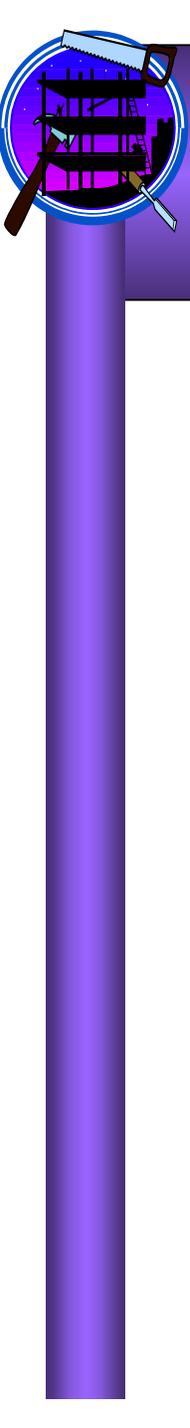
- The ultimate trade-off method allowing you to trade-off across building systems through the use of annual, hourly simulation tools and a baseline building.
- The only real way to deal with unique designs, renewables, high-efficiency equipment, etc.
- The basis of the energy portion of the LEED rating
- Limits allowable energy costs of the design to those of a building meeting the Standard





Section 12 - Normative References

- Normative (read “mandatory”) reference documents
- Includes test methods, rating procedures, and other standards



Assembly U-Factor, C-Factor, and F-Factor Determination (Normative Appendix A)

- Includes pre-calculated U-factors, C-factors, and F-factors
 - Above-grade walls
 - Below-grade walls
 - Floors
 - Slab-on-grade floors
 - Opaque doors
 - Fenestration





Building Envelope Criteria (Normative Appendix B)

- Actual prescriptive requirements tables for 26 different climate bins
- These are in an appendix because they would have taken up too much space in Chapter 5 and would have broken up the continuity of the text of the Standard



Methodology for Building Envelope Trade-Off Option in Subsection 5.4 (Normative Appendix C)

- The gory details of how the envelope trade-off option is implemented
- For those familiar with the “old” ENVSTD trade-off, this new trade-off allows trade-offs between roof and wall elements. The “metric” of trade-off is ultimately an energy dollar trade-off.



Climate Data

(Normative Appendix D)

- Climatic data for a number of US, Canadian, and international locations
- HDD65 and CDD50 for use in envelope calculations
- Heating and cooling design temperatures and the old “number of hours between 8 am and 4 pm with Tdb between 55 and 69” for HVAC calculations



Informative References

(Informative Appendix E)

- Other useful references that are not mandatory
- In general, these are not consensus documents so ASHRAE procedures do not allow them to be mandatory references



Informative References (Informative Appendix F)

- Information on addenda to 90.1-1999